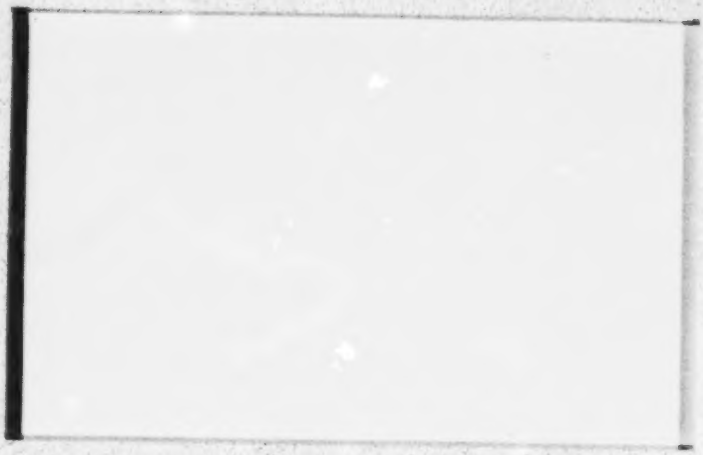

Consumers' Gas

FIELD EVALUATION OF IMPROVED DOMESTIC GAS FURNACES IN THE TORONTO AREA - PHASE II

FINAL REPORT BY:

THE CONSUMERS' GAS COMPANY LTD.

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources. Canada

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SUMMARY

Over the 1982/83 and 1983/84 heating seasons, Consumers' Gas Company Ltd., through its Research and Special Projects Department, completed a field testing program to monitor the operation and evaluate the performance of two Lennox G-14 pulse combustion, high efficiency condensing gas furnaces.

Through a weekly "flip-flop" monitoring approach, daily heating systems performance and consumption, degree-day and ambient temperature data were gathered and analyzed to compare the seasonal performance of the new generation heating appliances against existing, conventional gas equipment.

This report covers much of the work carried out and discusses pertinent project findings, like problems encountered and occupant perception, together with an account of the experimental procedure.

INTRODUCTION

As per the requirements of a project funded by Supply and Services Canada, the Research and Special Projects Department of Consumers' Gas conducted a field trial of two Lennox G-14, high efficiency, condensing, pulse combustion residential gas furnaces, over the 1982/83 and 1983/84 heating seasons.

The Combustion and Carbonization Research Laboratory (CCRL) of the Department of Energy, Mines and Resources was designated as the scientific authority for the project.

Two occupied, single family dwellings in the Toronto area were selected as test sites. The test units were installed in parallel with the existing, conventional gas heating appliances in order to take advantage of the "flip-flop" monitoring approach. Each appliance was operated on alternate weeks, with data on gas consumption, degree-days, hours of furnace operation and number of on-cycles recorded daily. Hourly, ambient temperature data were obtained.

This report contains an evaluation of the data, to arrive at the seasonal efficiency of the test furnaces, in a "real world" situation and to obtain an indication of savings to be realized, over heating with conventional gas systems, together with experience on the functional performance of the test units.

1.0 DESCRIPTION OF SYSTEM UNDER EVALUATION

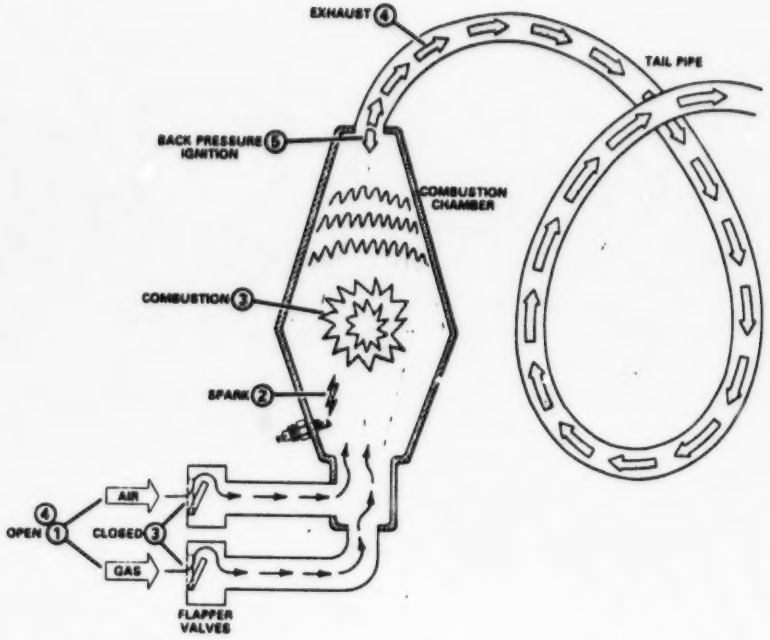
In this field testing programme, two Lennox G-14 series, high efficiency, condensing furnaces were evaluated. These units employ the Pulse Combustion Process, which is illustrated and described in Figure 1.

These units are representative of the design philosophy behind new generation furnaces, which aim at maximizing the steady state thermal efficiency and, of more practical interest, the seasonal efficiency, for much reduced heating costs.

Manufacturers claim combustion efficiencies over 96%, with seasonal efficiencies lower by a few percentage points only. This is achieved principally through the introduction of forced venting, which allows good combustion with very low excess air levels, and the use of a condensing heat exchanger located in the air stream. This additional heat exchanger further extracts heat, to the point of reducing the temperature of the combustion products below their dew point. In so doing, additional sensible heat and latent heat, which otherwise would be lost, carried out by the flue products, are recovered. The extraction of latent heat induces condensation of water vapour products, which are drained out.

The temperature of the exhaust products is relatively low and, in fact, these units are vented through rigid plastic pipe.

The power venting feature also eliminates the need for a conventional chimney and, instead, venting can be effected directly through a wall. This arrangement reduces off-cycles or stand-by losses, which can translate in significant reduction in fuel consumption.



1 - Gas and air enter and mix in combustion chamber.
2 - To start the cycle a spark is used to ignite the gas and air mixture. (This is one 'pulse').
3 - Positive pressure from combustion closes flapper valves and forces exhaust gases down a tailpipe.
4 - Exhaust gases leaving the chamber create a negative pressure. This opens the flapper valves drawing in gas and air.
5 - At the same instant part of the pressure pulse is reflected back from the tailpipe causing the new gas and air mixture to ignite. No spark is needed. (This is another 'pulse').
6 - Steps 4 and 5 repeat 60 to 70 times per second forming consecutive 'pulses' of 1/4 to 1/2 Btu each.

FIGURE 1. PULSE COMBUSTION PROCESS

In the Lennox G-14 units, electronic direct spark ignition is used to initiate combustion, which is then sustained automatically, as described in Figure 1. Sealed combustion (ie. outside combustion air) is employed, to further maximize the seasonal efficiency.

A small blower is used to purge the combustion chamber before and after each heating cycle and to provide proper air mixture for start-up. A flame rectification sensor verifies ignition and/or loss of combustion during a cycle, locking out the system if necessary. Obstructions to the air intake or exhaust outlet also shut down the unit immediately. The furnaces is shown in Figure 2.

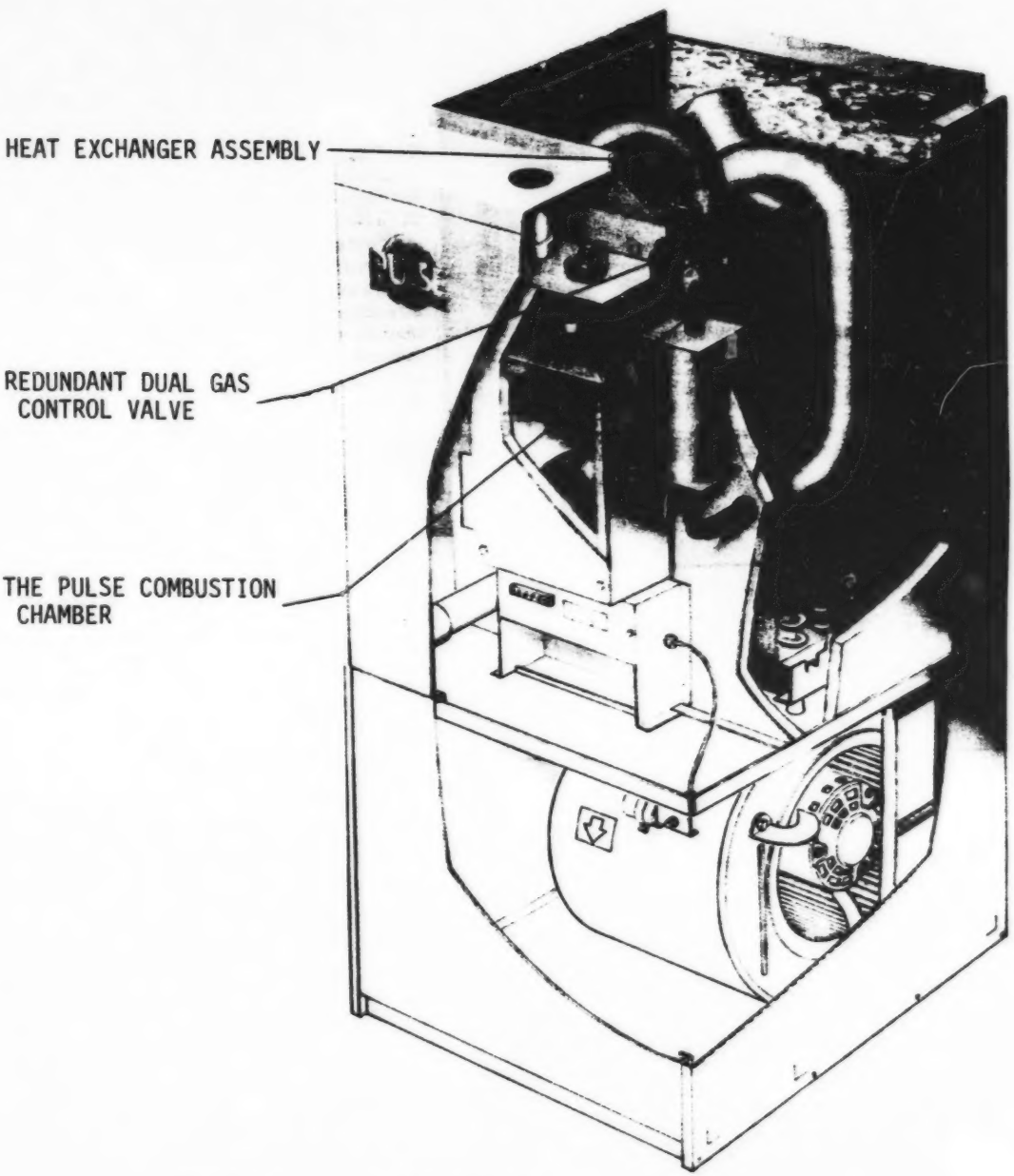


FIGURE 2. PULSE FURNACE

2.0 FIELD TESTING AND EVALUATION PROCEDURE

In order to assess the functional performance of the units and to provide a measure of their seasonal efficiency from a practical standpoint, it was decided to operate the two condensing furnaces at each test site in parallel with the existing conventional furnaces, whose energy consumption would then be taken as reference.

At each site changeover between condensing and conventional furnaces were carried out on a weekly basis, in what is referred to as the "flip-flop" monitoring approach. Daily readings of furnace gas consumption, degree-days, hours of furnace operation and number of on-cycles were recorded at about the same time. If discrepancies occurred, results were normalized for a twenty-four hour time interval for computational purposes.

Furnace performance was calculated on the basis of energy consumption per degree-day. Seasonal efficiency was described by comparing the cubic feet of natural gas consumed by the test unit to those used by the existing conventional unit. The indicated percentage improvement was added to the generally accepted conventional furnace Annual Fuel Utilization Efficiency (AFUE) of 65% (Ref. 1), to arrive at an AFUE for the units under test.

It is recognized that field testings are very time and site-sensitive and that by nature are performed under "non-controlled" conditions. Therefore, results should be taken only as indicative of the seasonal performance of the units under test.

A higher frequency of change-over (daily rather than weekly) would have helped in averaging out to a greater degree, differences in operating conditions,

which inevitably occur in a field test type of environment. However, isolating one furnace and activating the other one required a fairly involved procedure,* which would have demanded too much from the patience of the homeowners, entrusted with taking the readings and doing the change-overs.

Variables like climatological conditions cannot be controlled and, in fact, for a given outdoor temperature or number of degree-days, it is totally feasible for a test site to require less energy in a sunny day, than under cloudy or windy conditions, to maintain a given inside temperature. Other difficult to control variables include people's living habits, which can affect heating load demand, under otherwise identical conditions.

As expected, results gave a wide spread in the readings of cubic feet of gas consumed per degree-day and to have a better representation of the relationship between the two variables, a linear regression analysis was performed.

It should be pointed out that in order not to penalize the seasonal efficiency potential of the condensing furnaces during their operation, the vent outlets from the conventional furnaces were sealed. Similarly, to fully eliminate water heater chimney losses and potential data discrepancies, gas fired water heaters were replaced with electric units.

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* SEE APPENDIX A

3.0 INSTRUMENTATION

In order to collect necessary data to measure the seasonal efficiency of the appliances under test, the three sites were equipped with the following monitoring instrumentation:

GAS SUBMETERS - Canadian Meter Co. Type A-225 with digital cubic feet per minute read-out, for higher resolution, to measure gas input to individual units.

DEGREE DAY RECORDERS - Hidy Brown Recorders Company, Hidy degree-day recorders, single dial model. Monitor the number of degree-days over the heating season, for degree-day/energy input correlation analysis.

ELAPSED TIME INDICATORS - Hecon of Canada Ltd. type 406, code number G0406416. To monitor the duration of each heating cycle.

EVENT COUNTERS - Hecon of Canada Ltd. electronic totalizing counters, series G0716, to count the number of heating cycles.

In addition, a Furnace Efficiency Meter model O from RAB Dedesco Ltd. allows for easy on site flue gas analysis and efficiency measurements, from condensing systems.

Typical instrumentation set-up is shown in Figure 3.

Data were read and recorded daily at a predetermined time (24 hour cycle).

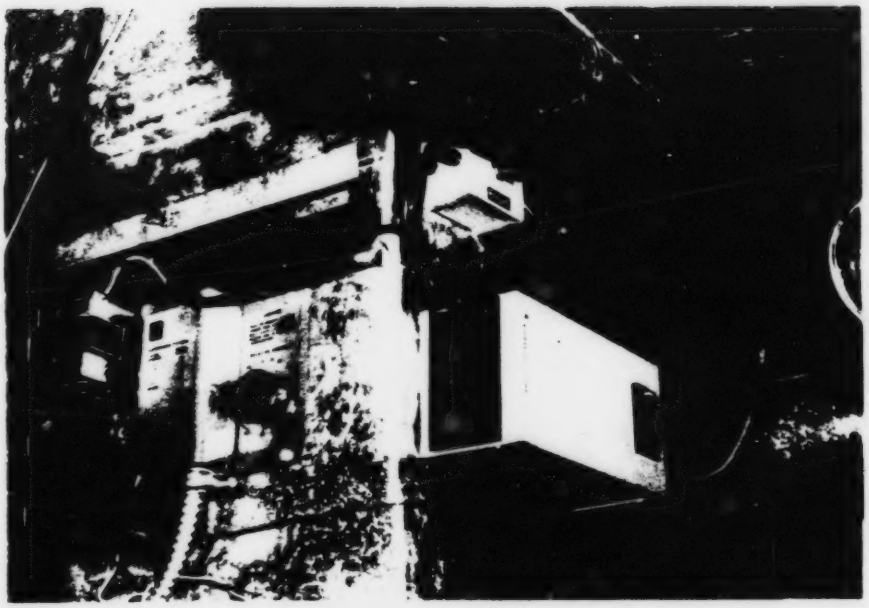


FIGURE 3. TYPICAL INSTRUMENTATION

Showing event counter with total hour meter

4.0 INSTALLATION

The two test sites selected are the residences of company employees. Weekly changeover between heating systems and daily data collection were carried out by the residents.

The two houses, representative of model, size and construction type of most common households, are shown in Figures 4 and 5.

The "Homeowner Questionnaires" in Appendix "B" contain additional information on the test sites, heating systems and demographic data.

The two test furnaces are representative of current designs as far as weight, dimensions and electric hook-up requirements. Venting differs from common practice, in that a chimney is not required. These units can be vented through an external wall, as shown in Figure 6, where the combustion air inlet (these furnaces operate with sealed combustion) is also visible. Furnace installation set ups are shown in Figure 7 and 8.

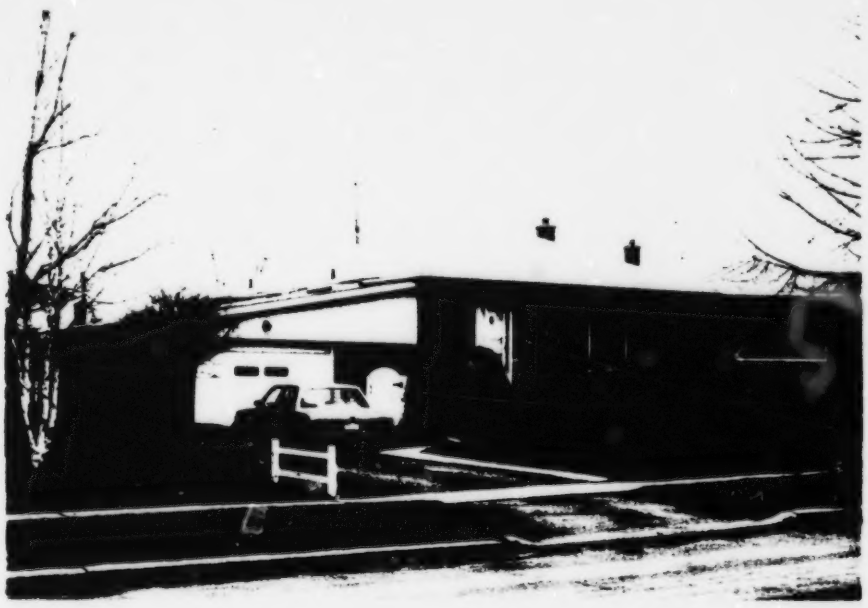
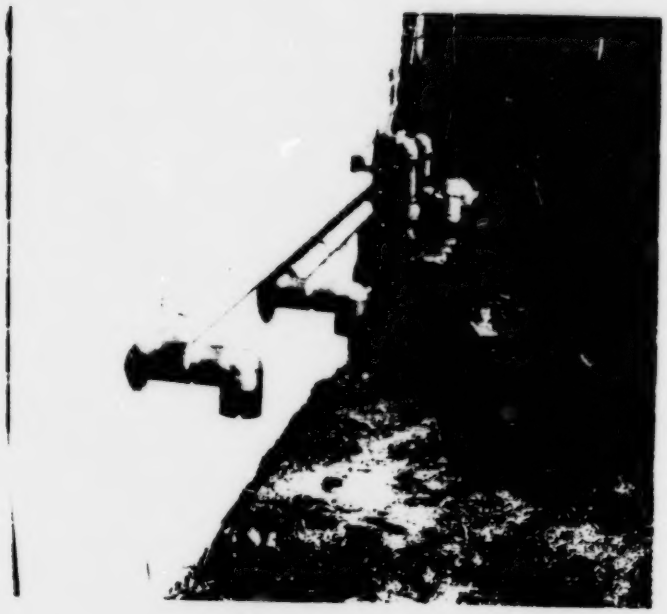
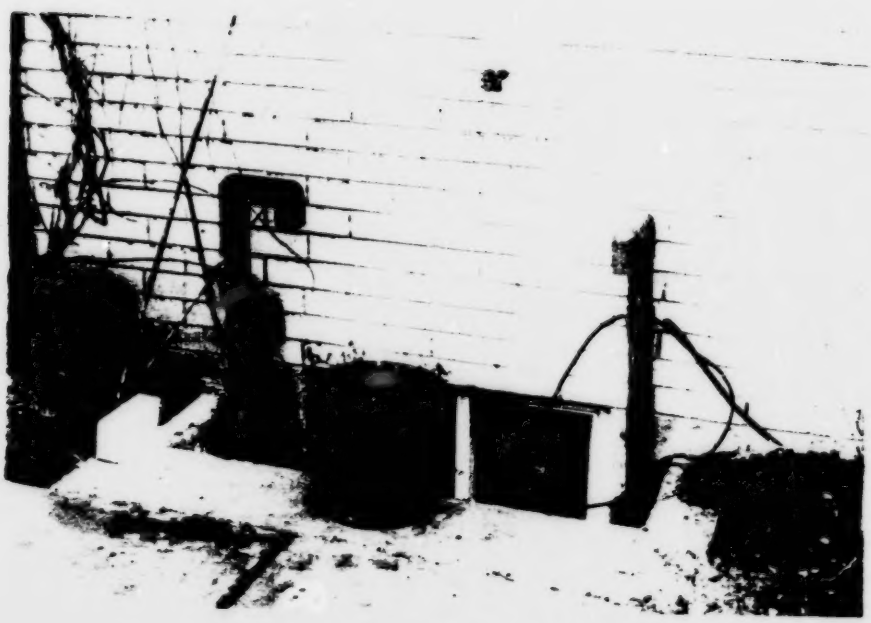


FIGURE 4. SCARBOROUGH TEST SITE

FIGURE 5. BRAMPTON TEST SITE



Scarborough



Brampton

FIGURE 6. COMBUSTION AIR INLET AND OUTLET OF COMBUSTION PRODUCTS

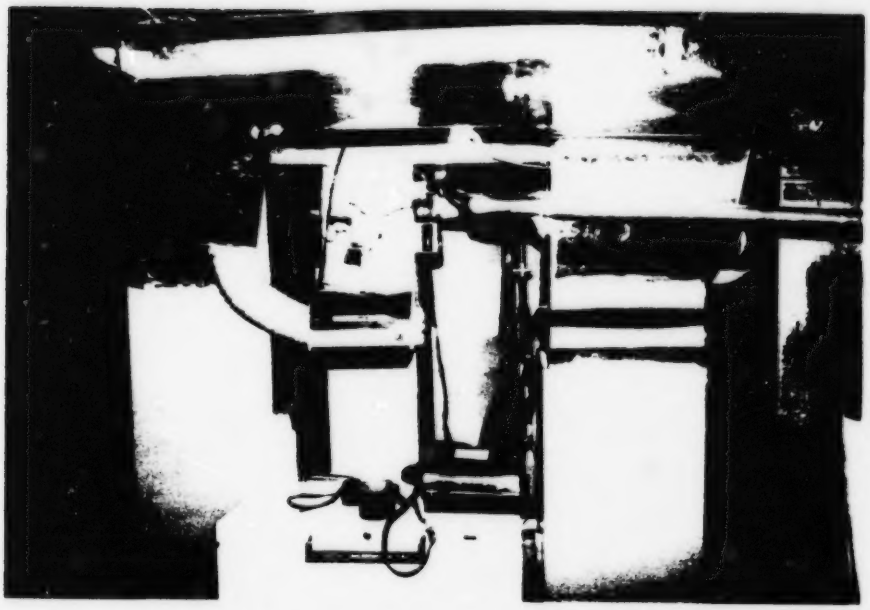


FIGURE 7. FURNACE INSTALLATION SET-UP - SCARBOROUGH SITE

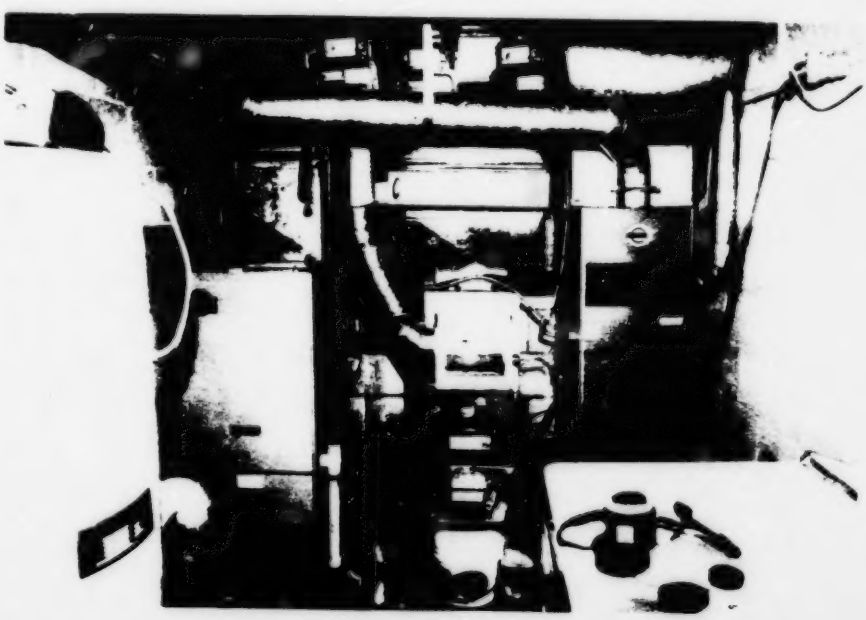


FIGURE 8. FURNACE INSTALLATION SET-UP - BRAMPTON SITE

5.0 SITE READINGS AND RESULTS

5.1 Scarborough

The site at Scarborough, (Figure 4) is a brick construction, two-storey, residential house with a floor area of 1200 ft^2. The high efficiency condensing gas furnace is installed in parallel with the existing gas furnace, with interconnecting ductwork provided with isolating dampers, to exclude the idle furnace from the circulating air stream, while the other is in operation. Total heated area is 2400 ft^2.

Readings were taken daily on an alternate week basis and are summarized in Tables 1 and 2. Sometimes switchover was not performed at the specified interval and the same week may show readings for both furnaces.

It should be noted that the pilot of the conventional furnace continued to burn even when the high efficiency unit was in operation. However, the vent outlet from the conventional furnace was blocked with a sliding gate during those times, to prevent chimney losses, therefore the pilot essentially contributed to heating the conditioned space and its consumption was included in the cubic feet of gas shown for the high efficiency furnace.

The 1982-83 heating season results indicate that the conventional furnace consumed 14.23 cubic feet of natural gas per degree day F, while the pulse furnace burned 9.83 CF/DD.

These figures indicate a reduction in gas consumption of 30.9%, yielding an equal (30.9) percentage in savings to be realized over the cost of heating that particular site with the conventional furnace.

TABLE 1. SCARBOROUGH TEST SITE, 1982-83 TEST RESULTS

WEEK #	CONVENTIONAL CF	D-D	CF/DD	HIGH EFFICIENCY FURNACE CF	D-D	CF/DD
1				2578	311	8.29
2				3219	325	8.99
3	3892	241	16.15			
4				3630	118	11.27
5	4633	279	16.6			
6				2271	200	11.35
7	4902	305	16.07			
8	2774	189	14.68	2408	310	7.77
9	3228	219	14.74			
10				2192	200	10.96
11	3629	255	14.23	1084	96	11.29
12				3590	343	10.47
13	4869	351	13.87			
14				3828	397	9.64
15	1293	158	8.17			
16	2075	202	10.27			
TOTALS	31295	2199	14.23	24934	2537	9.83

GAS SAVINGS: $\frac{(14.23 - 9.83)}{14.23} \times 100 = 30.9\%$

HEATING COST SAVINGS: 30.9% of cost to heat with conventional system

TABLE 2. SCARBOROUGH TEST SITE, 1983-84 TEST RESULTS

WEEK #	CONVENTIONAL CF	D-D	CF/DD	HIGH EFFICIENCY FURNACE CF	D-D	CF/DD
1				5115	484	10.57
2	4651	287	16.21			
3				4270	397	10.76
4	7555	430	17.57			
5				3826	329	11.63
6				4549	388	11.72
7	5882	342	17.20			
8	3837	222	17.28			
9				4832	433	11.16
10	5762	362	15.92			
11				3160	317	9.97
12	4917	304	16.17			
13				5162	465	11.10
14	6201	381	16.28			
15				3558	380	9.36
16	1816	163	11.14			
17				1450	175	8.29
18	652	80	8.15			
TOTALS	41273	2571	16.05	35922	3368	10.66

GAS SAVINGS: $\frac{(16.05 - 10.66)}{16.05} \times 100 = 33.6\%$

HEATING COST SAVINGS: 33.6% of cost to heat with conventional system

Put another way, one can say that the old furnace is 30.9% LESS efficient than the new (pulse) one. If we assume the old one to have an AFUE of 65%, then the extrapolated seasonal efficiency of the pulse unit, at that test site, is:

$$65 = (1-0.309) \times \text{EFF (PULSE)} \quad (\%)$$

$$\text{EFF (PULSE)} = \frac{65}{(1-0.309)} = 94.07\%$$

During the 1983-84 heating season consumption figures shown were 16.05 cubic feet per degree day for the conventional furnace and 10.66 for the high efficiency test unit.

These values indicate a reduction in fuel consumption of 33.6% and, again, savings of also 33.6%, over the cost of heating with a conventional gas furnace. The extrapolated value for the efficiency of the test unit indicates that the pulse furnace operated at 97.8% seasonal efficiency, always taking the old furnace to operate at 65% (ie. 50.56% increase). The discrepancy from the previous year results is well within the accuracy limits of this type of field test.

The figures for savings and increase in efficiency are site specific and should only be taken as indicative of the potential that the new condensing furnaces offer for saving energy and reducing heating costs.

Performance in the field is dependent on many uncontrollable variables, some

of which are related to climate (wind, clouds) others to living patterns of habitants (frequency of front door opening, inside temperature setting ...) location (south or north exposure ?) etc. In fact, over a heating season, data usually indicate a fairly large scatter of gas consumption at any given level of degree-days, for the same test site.

To have a measure of the possible significance on the results of the scatter of cubic feet of gas required per degree day, a linear regression analysis was performed on the data collected over the 82-83 heating season. The least squares method used allows to plot a line, which uniformily divides the dependent data points (cubic feet) per degree day levels.

The results with this type of data manipulation are also site-specific, but could be used to extrapolate fuel consumption per degree-day on the basis of more "averaged" conditions.

Therefore, (See Figure 9) for a typical 3800 F. degree day Toronto area heating season, the conventional furnace would require 38,153 CF of gas, while the pulse unit would only use 29,293 cubic feet. These figures translate into savings of 23.2%, which would bring the seasonal efficiency of the pulse furnace to 84.7%, opposite 65% for the conventional.

These performance figures, although lower than those previously indicated on a gross basis for the same year (30.9% savings 94.07% AFUE), are nonetheless significant in the sense that they corroborate the notion that high efficiency gas appliances do allow to effect considerable energy savings under most operating conditions, with correspondingly lower heating costs.

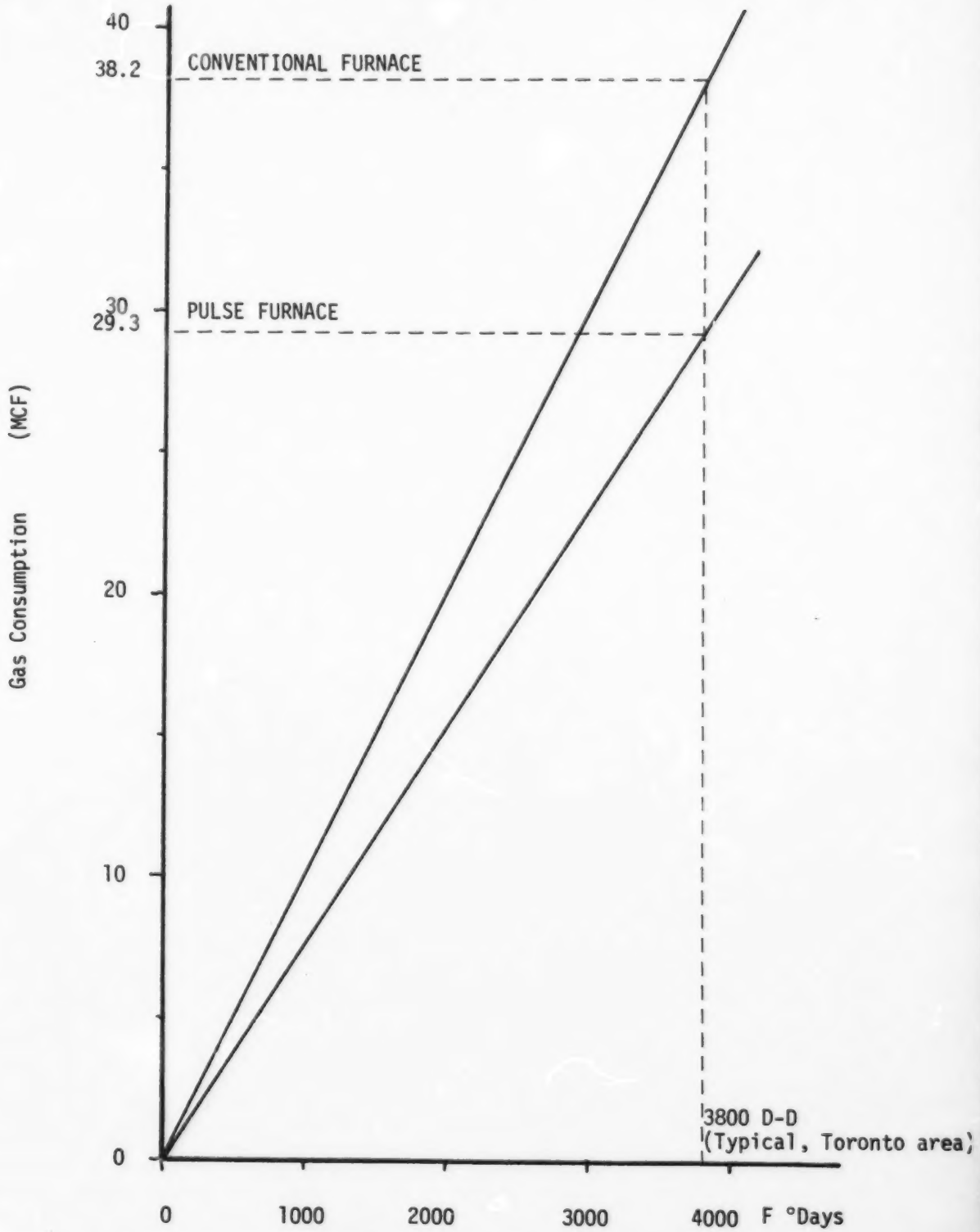


FIGURE 9. LINEARIZED GAS CONSUMPTION VS. DEGREE DAYS

5.2 Brampton

The house in Brampton (Figure 5) is a two-storey, detached, brick construction, with a total heated area of 3300 ft^2, including the finished basement.

As with the other site, the furnace under test is installed in parallel to the existing one (Figure 8). Readings of data were taken daily, with weekly changeover between systems.

While in standby mode, the vent outlet from the conventional furnace was blocked to prevent exfiltration of conditioned air. The pilot, however, was constantly on, in effect contributing to heat-up the house. Therefore, its gas consumption was charged to that of the test furnace, when this was in operation.

During the first heating season (1982-83) the conventional furnace was plagued with repeated problems of spillage of combustion products from the draft diverter and occasional roll-out of flames on start-up.

A poorly designed B-vent type chimney, together with some depressurization of the furnace room, due to inadequate air circulation and local leakage of the return air side, impeded adequate chimney flow of combustion products. Therefore, the conventional furnace did not provide sufficient useful data.

Table 3 shows data collected over that first heating season with the high efficiency furnace only.

TABLE 3. BRAMPTON TEST SITE, 1982-83 TEST RESULTS

WEEK #	CONVENTIONAL CF	D-D	CF/DD	HIGH EFFICIENCY FURNACE CF	D-D	CF/DD
1				2909	274	10.62
2				2245	249	9.02
3				2724	267	10.20
4				2846	269	10.58
5				3244	272	11.93
6				4204	356	11.81
7				3136	279	11.24
8				3175	272	11.67
9				4330	327	13.24
10				1963	241	8.15
11				2527	236	10.71
12				2411	219	10.99
13				1830	190	9.63
14				1809	223	8.12
15				2786	260	10.72
16				1415	229	6.2
17				1136	176	6.44
18				1111	164	6.77
19				1845	213	8.66
20				1064	155	6.85
	TOTALS			48710	4871	9.68

During the 1983-84 heating season, the conventional furnace consumed 13.77 CF/DD, against 10.00 CF/DD of the pulse furnace, indicating that it effects savings of 27.4% (ie. a 27.4% reduction in fuel consumption, compared to the conventional unit).

Again, assuming a seasonal efficiency of 65% for the conventional furnace, the condensing unit will show to be 65/(1-0.274) = 89.5% efficient.

This result would indicate a fairly significant difference of about four percentage points, with respect to Scarborough's results. However we are not dealing with a hard reference and if we assumed the conventional furnace to have a seasonal efficiency of 68% rather than 65%, then the discrepancy would no longer be there.

Indeed, the conventional furnace did consume less in Brampton (13.77 CF/DD) than in Scarborough (16.05 CF/DD), justifying the suspected difference in seasonal efficiency at the two sites.

One should keep in mind, however, that the nature of this type of testing is not geared towards producing quantitative results. Rather, a qualitative assessment of the functional performance is obtained, together with a relative measure of potential energy (and heating costs) savings, by monitoring the specific fuel consumption per degree day.

Table 5 gives typical steady state efficiency results for both sites.

TABLE 4. BRAMPTON TEST SITE, 1983-84 TEST RESULTS

WEEK #	CONVENTIONAL CF	D-D	CF/DD	HIGH EFFICIENCY FURNACE CF	D-D	CF/DD
1	1696	184	9.22			
2				2346	200	11.72
3	2152	193	11.15			
4				1948	215	9.06
5	3323	246	13.51			
6				3312	315	11.60
7	3995	305	13.00			
8	5305	395	13.43			
9	4861	344	14.13			
10				2989	311	9.61
11				4451	404	11.02
12				3675	335	10.97
13				2579	293	8.80
14	3630	302	12.02			
15	3877	265	14.63			
16				1774	208	8.53
17				2398	242	9.91
18				3530	305	11.57
19	5615	369	15.22			
20	3767	227	16.59			
21	4324	252	17.16			
22	2712	179	15.15			
23				2007	176	11.4
24				692	118	5.86
25	2576	188	13.70			
TOTALS	47833	3449	13.77	31701	3122	10.0

GAS SAVINGS: 27.4%

HEATING COST SAVINGS: 27.4% of heating with conventional gas system

TABLE 5. STEADY STATE EFFICIENCY

TEST NO.	1	2
Outside Temp. °C	27	27
Room Temp. °C	23	23
Flue Gas Temp. °C	35	320
Actual Input, kW	19.6	23.4
Rated Input, kW	23.4	23.4

Flue Gas Analysis:

Carbon Monoxide (CO), ppm	1	15
Nitrous Fumes (NO_x), ppm	30	40
Oxygen (O_2), %	8.3	10.5
Nitrogen (N_2), %	83.9	82.7
Carbon Dioxide (CO_2), %	7.8	6.8
Unburned Hydrocarbons, ppm	8	9
Rate of Condensation, kg/h	2.08	---
Condensation pH	3.7	---
Calculated Excess Air, %	47	67
Calculated Combustion Effiency, %	96.6	72.5

TEST NO.	APPLIANCE	MANUFACTURER	SERIAL NO.	
1	FWAF	G14Q3-80-2	ED-16131	PULSE
2	FWAF	HGB100	D139908	CONVENTIONAL

6.0 COMMENTS ON THE FUNCTIONAL OPERATION

The functional performance of the two furnaces under test has been totally satisfactory, with no serious (or unusual) faults attributable to the particular design of these pulse combustion units.

The Scarborough site did not require any service call, while the site in Brampton did register several "no-heat" situations. However, the ones occurring during operation of the pulse furnace were not attributable, usually, to the unit itself. Several calls were prompted by a fault found (eventually) in the electronic thermostat.

In one instance, short cycling and ignition difficulty was observed. A service check pointed at a Combination Fan/Limit Control as the source of the problem, which disappeared after replacing the control.

Always at the Brampton site, the test furnace was fitted with a larger capacity, factory replacement, direct drive blower. The change was prompted by the need to adequately distribute the circulating air in a fairly restrictive ductwork system and increase the comfort level of the occupants.

A visual inspection of both furnaces did not reveal any particular sign of deterioration. In an attempt to determine hard to detect problems without a thorough dismantling of the units, condensate samples were collected and analysed to determine their acidity level and ion content. Dissolved metals like iron, nickel, chronium, etc. would indicate the occurrance of corrosion, if present in high enough concentration.

A typical, for both sites, analysis result is shown in Figure 10. This particular combustion products condensate sample was collected in Brampton after more than two heating seasons.

The very small concentrations of metallic ions sustain the reassuring observation that no corrosion at any significant level is taking place as a result of the acidic nature (pH = 4.7) of the condensate. Furthermore, if we assume a linear rate of corrosion over the years, the measured ionic concentrations give some reassurance as to the expected longevity of the unit's heater exchanger system.

In fact, if we consider that the pulse test furnace condenses out at an average rate of 2 l/hr and that over a typical heating season the same furnace will operate for a total of 2300 hours (based on field test observations), then we can calculate that after ten years of operation, the furnaces would lose 3.22 g. of iron, 0.92 g. of chronium and 2.76 g. of nickel, indicating that its steel and stainless steel components are holding out very well. It should be noted, however, that aluminum will be lost at a much higher rate, for a total loss of 18.4 g. after 10 years. Aluminum certainly comes from the aluminized steel casting of the combustion chamber, which will lose more iron if the protection offered by aluminum is lost through the years. However, the hefty casting should certainly outlast the furnace life. In any case, further studies would be desirable to determine the actual rate of corrosion of the main metallic constituents.

Also a total of 9.2 g. of silver will be lost after ten years. This metal must come from silver solder used in assembling the refrigeration coil type condensing, secondary, heat exchanger. This could become a sensitive issue

pH:4.7

ION	mg/l
Si	.05
Al	1.1
Fe	.07
Ca	.11
Mg	.01
Na	.01
K	1.0
Ti	.01
Mn	.02
P	.02
Ba	.02
Cr	.02
Zr	.01
Cu	.2
Ni	.06
Pb	.03
Zn	.4
Va	.01
Sr	.01
Co	.01
Mo	.02
Ag	.2
Cd	.02
Be	.01
Bo	.5
Cl	.02
SO_4	.03

FIG. 10. ANALYSIS OF COMBUSTION PRODUCTS CONDENSATE (TYPICAL)

in relation to maintenance and service requirements; however, to draw definitive conclusions at this moment, specific information on the design and manufacture of the secondary heat exchanger would be needed. It would be useful to follow up with heating contractors, to gather information on their service experience with their units in the field.

It should also be noted that, in the particular case of the sites under test, no problems associated with the presence of unusually high concentration of chlorides exist. This is expected, since the combustion air is drawn from outside and thus is not subject to contamination from fumes emanating from some common household items high in chlorine content (bleach, swimming pool chemicals, paint strippers, etc.). Field experiences with some other condensing appliances have shown failures due to attack of stainless steel components by halogenated products which, when present in the combustion air and in the presence of a flame, will liberate halogen ions to form an acidic solution when condensation occurs.

Condensing heating appliances are always power vented and it should be fairly easy to draw the air of combustion from outside. This should become an industry wide standard.

Specific to the design of the pulse furnaces is occupants' and neighbors' perception of the noise level associated with their operation.

Occupants did not find these units to be particularly noisy. Neighbors, at times, complained about it. Measurements were taken and reported in the following table.

TABLE 6. MEASURED SOUND LEVELS

LOCATION	DISTANCE FROM	HEIGHT ABOVE	DECIBELS (dBA)
Furnace Room	Furnace, 3 ft.	Floor, 5 ft.	58, Pulse Furnace (including air blower) 53, Conventional Furnace
Outside	Inlet/Outlet 4 ft.	Ground, 5 ft.	64

Sound levels are not high. Any discomfort must be associated with the rambling noise being of low frequency.

The manufacturer has eventually made available mufflers for both the inlet and outlet. These were not installed at the test sites, therefore we cannot comment on their effect.

7.0 CONCLUSIONS

- The combustion furnaces under test operated satisfactorily, at the complete satisfaction of the homeowners.
- Savings over conventional gas furnaces ranged between 27 and 34% over two heating seasons of operation.
- Seasonal efficiencies were extrapolated based on gas savings and an assumed seasonal efficiency of 65% for the conventional units. Results ranged between 89 and 94%.
- Noise levels associated with the pulse combustion operation are not excessive, measuring 58 dBA in the furnace room and 65 dBA outside. The sound audible outside from the inlet and outlet pipes of the sealed combustion units is a low frequency rumble, fastidious to some people.
- Analysis of condensate did not reveal suspiciously high concentration of metals. Attack from acidic condensate does not seem to be a problem.

8.0 RECOMMENDATIONS

- The field evaluation should be terminated and the sites restored to their original condition.
- Sealed combustion is a highly desirable feature for the longevity of condensing heating appliances and it should be promoted to become an industry wide standard.

9.0 REFERENCES

1. Ferguson, J.E., Sullivan, H.F., "Analysis of Residential Space Heating Systems in Canada", final report prepared by Spider Engineering Associates (Waterloo) Inc., for DBR/NRC, DSS Contract No. OSX82-00026, March 1984.

APPENDIX A

SWITCHOVER PROCEDURE

TO SWITCH FROM PULSE FURNACE TO OLD FURNACE

STEP

1 Note gas meter, degree day, events and hours of operation timer readings on data sheet, then zero timer and event counter.

2 Move toggle switch (found on upper shelf of Pulse furnace) to "OFF" position.

3 If blower is running, wait for it to stop.

4 Shut off power to Pulse furnace (ceiling switch)

5 Move toggle switch on small grey box (found on return air plenum just above event counter) to "CONV" position.

6 Push damper blades into supply and return ducts on pulse furnace.

7 Remove damper blades from supply and return ducts on old furnace.

8 Remove blast gate from vent pipe on old furnace, and push red plug into socket on blast gate blade.

9 Turn on power to old furnace (ceiling switch)

10 Move toggle switch (found on top of Pulse furnace) to "OLD" position. Burner on old furnace should light (if thermostat is calling for heat) and blower should come on shortly after - event counter should then count "1" and timer should be running.

TO SWITCH FROM OLD FURNACE TO PULSE

1 Note all meter readings on data sheet and reset event counter and timer to zero.

2 Move toggle switch (found on upper shelf of Pulse furnace) to "OFF" position.

3 If blower is running wait for it to stop.

4 Shut off power to old furnace (ceiling switch)

5 Move toggle switch on small grey box (found on return air plenum just above event counter) to "PULSE" position.

6 Push damper blades into supply & return air ducts on old furnace.

7 Remove damper blades from supply & return air ducts on old furnace.

8 Disconnect red pin jack from blast gate blade of old furnace, and slide blade all the way into the slot in the furnace vent pipe.

9 Turn on power to pulse furnace (ceiling switch)

10 Move toggle switch (found on top of pulse furnace) to "PULSE" position.

APPENDIX B

HOMEOWNER'S QUESTIONNAIRES

HOMEOWNER QUESTIONNAIRE APPENDIX B

SITE: BRAMPTON

GENERAL INFORMATION

Name of occupant COMPANY EMPLOYEE
Installation address BRAMPTON, ONTARIO
Single Family Residence? YES Multiple? --
Approx. age of structure 24 yrs. How long have you resided? 21 yrs.
No. of occupants 6 Adults 6 How many are employed? 5
If two or more, which hours 9 - 5
What indoor temperatures do you maintain:
While at work 72°F Hours
Daytime 72°F Hours
Nightime 72°F Hours

STRUCTURE

Number of stories Two Floor area 1100 ft^2
Type of construction (Brick or frame) Brick Style 2 story stack
Does it have storm windows Yes Storm doors Yes
Is it insulated Yes Was any insulation installed recently No
If so, when Where, and thickness Type
In your opinion, is building of tight construction? Fair
Do you have a basement Yes Is it heated Yes
No. of basement windows 6 Do they close tightly? Yes
Is the door to the basement normally closed Yes
No. of exhaust fans: Kitchen 2 Bathroom 1 Other
Where is thermostat located (room) Hallway Inside or Outside Wall Inside
Does this house have a fireplace yes Does it have a good damper yes

APPLIANCES

Does this residence have a gas light? Two
Input or number of mantles 4 mantles, 4.5 BTUH EACH
Does this residence have an electric or gas range Gas
If Gas: Type Moffatt Location Main Floor

...cont'd

HOMEOWNER QUESTIONNAIRE CONT'D

APPLIANCES CONT'D

Does this residence have a gas grill? Gas Broiler

Hourly inputs 30,000 BTUH How often is it used? 1 hr/wk.

Does this residence have a gas or electric clothes dryer Gas

If gas: Location Basement Vented to outdoors? Yes

Size of vent pipe 4" Hourly input 26000 BTUH

How often is it used? 1 hr./day

Does this residence have a gas fired water heater No

Storage capacity _____ Hourly input _____

Size of flue pipe _____ Does this pipe connect to the same chimney as the heating system _____

Does this residence have air conditioning? Yes

Central yes Window units -- How many? --

HEATING SYSTEM

Present Furnace/Boiler:

Trade Name Anthes

Model HGB 100

Manufacturer Anthes

Rated Input 100,000 BTUH

Age Over 15 years

Type of Ignition Standing Pilot

Type of Venting Natural Draft

Test Furnace/Boiler:

Trade Name Lennox Pulse

Model G14Q3-80-2

Manufacturer ~~Lennox Industries~~

Rated Input 80,000 BTUH

Age 3 yrs.

Type of Ignition Direct, Spark

Type of Venting Forced

TEST CHANGES:

HOMEOWNER QUESTIONNAIRE

SITE: Scarborough

GENERAL INFORMATION

Name of occupant Company Employee
Installation address Scarborough, Ontario
Single Family Residence? Yes Multiple? _____
Approx. age of structure 24 yrs. How long have you resided? 24 yrs.
No. of occupants Two Adults Two How many are employed? One
If two or more, which hours _____
What indoor temperatures do you maintain:
While at work 65°F Hours 10:00 a.m.-2:00 p.m.
Daytime 72°F Hours Other Times
Nightime 65°F Hours 12:00 p.m. - 6:00 p.m.

STRUCTURE

Number of stories Single Floor area 1200 ft^2
Type of construction (Brick or frame) Brick Style Bungalow
Does it have storm windows yes Storm doors yes
Is it insulated yes Was any insulation installed recently yes
If so, when 1983 Where, and thickness ceiling Type _____
In your opinion, is building of tight construction? yes
Do you have a basement yes Is it heated yes
No. of basement windows 6 Do they close tightly? yes
Is the door to the basement normally closed No
No. of exhaust fans: Kitchen One Bathroom No Other -
Where is thermostat located (room) Hallway Inside or Outside Wall Inside
Does this house have a fireplace No Does it have a good damper _____

APPLIANCES

Does this residence have a gas light? No.
Input or number of mantles _____
Does this residence have an electric or gas range Gas
If Gas: Type Admiral Location Main Floor

...cont'd

HOMEOWNER QUESTIONNAIRE CONT'D

APPLIANCES CONT'D

Does this residence have a gas grill? Yes

Hourly inputs _____ How often is it used? Summer only

Does this residence have a gas or electric clothes dryer Gas

If gas: Location Basement Vented to outdoors? Yes

Size of vent pipe 4" Hourly input 26,000 BTUH

How often is it used? Once/week

Does this residence have a gas fired water heater No

Storage capacity _____ Hourly input _____

Size of flue pipe _____ Does this pipe connect to the same chimney as the heating system _____

Does this residence have air conditioning? Yes

Central Yes Window units _____ How many? _____

HEATING SYSTEM

Present Furnace/~~Boiler~~ XXXXXX:

Trade Name Lennox

Model GH6

Manufacturer Lennox Industries

Rated Input 100,000 BTUH

Age 24 years

Type of Ignition Stand Pilot

Type of Venting ~~Natural~~ Draught

Test Furnace/Boiler:

Trade Name Lennox Pulse

Model G-14Q3-80-2

Manufacturer Lennox Ind.

Rated Input 80,000 BTUH

Age 3 years

Type of Ignition ~~Direct & Spark~~

Type of Venting Forced

TEST CHANGES: